

# Simulations

## Peter Litchfield

- ❖ Standard detector
- ❖ Resolution comparison of standard and TA detectors
- ❖ Other TA detector configurations
- ❖ Scan of the TA data

# Standard detector

- ❖ Since last meeting, not a lot done:
  - A document (Nova-42) with a summary of results for many off-axis positions,  $\Delta m^2$ , neutrinos and anti-neutrinos was produced.
  - Minor improvement to the attenuation correction by subtracting the average noise **before** making the correction.
  - Gives slightly different results to those in Nova-42 but doesn't change any conclusions. I haven't repeated all the cases.

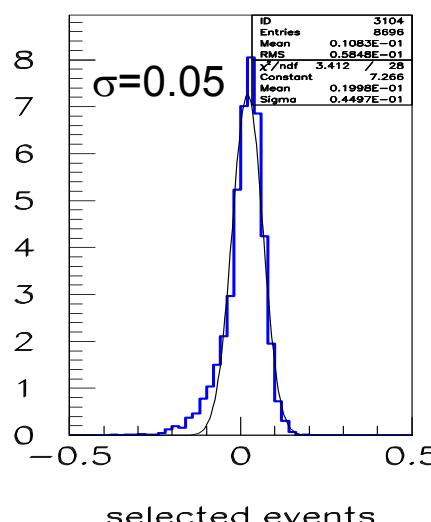
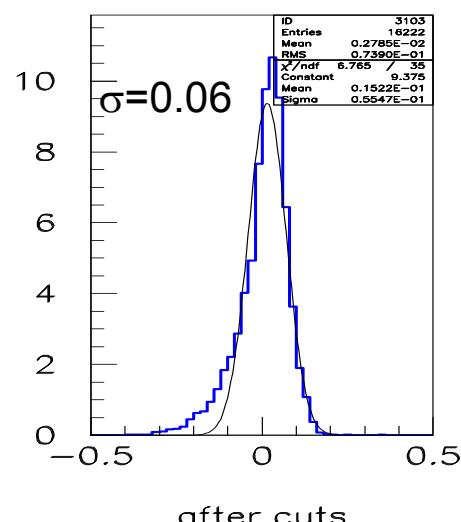
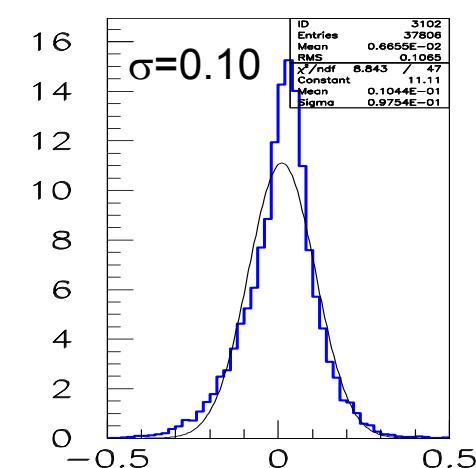
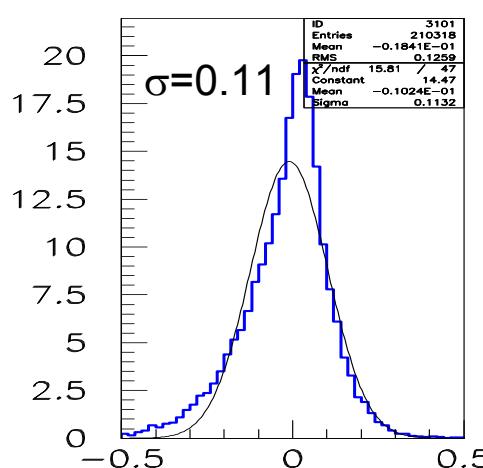
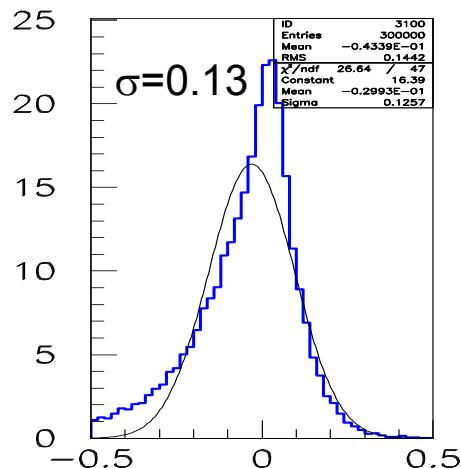
# Resolution Comparison

- ❖ I have compared the energy resolution, measured as the sum of the total pulse height in the event, for the standard and TA detectors. The comparison is written up in Nova-48
- ❖ The processing and selection of the events is the same for the two detectors (as far as possible).
- ❖ The resolution is parameterised following Stan as

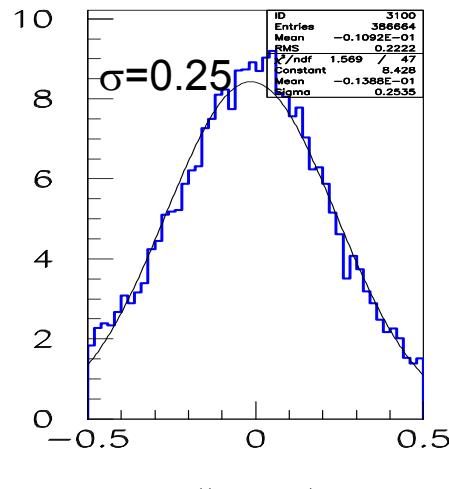
$$DELE = \frac{(\text{Measured energy} - \text{Truth energy})}{\sqrt{\text{Truth energy}}}$$

- ❖ Run conditions are  $\Delta m^2 = 0.0025 \text{ eV}^2$ ,  $\sin^2 2\theta_{13} = 0.1$ , only e CC events are considered.
- ❖ Resolution varies according to the cuts imposed, take at 5 points in the selection process.
- ❖ Resolution is a function of  $1-y$ , a linear correction is applied (see note)

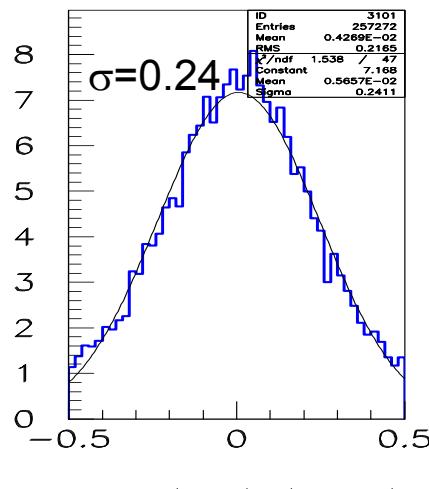
# TA detector resolution



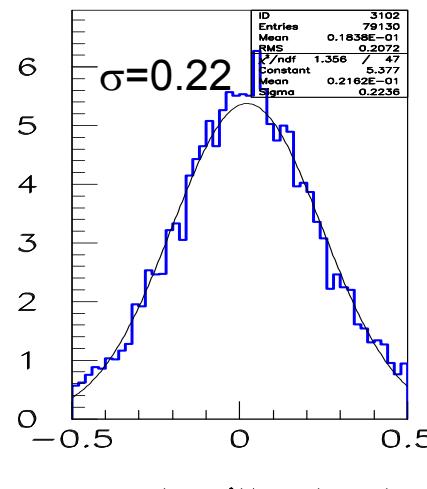
# Standard detector resolution



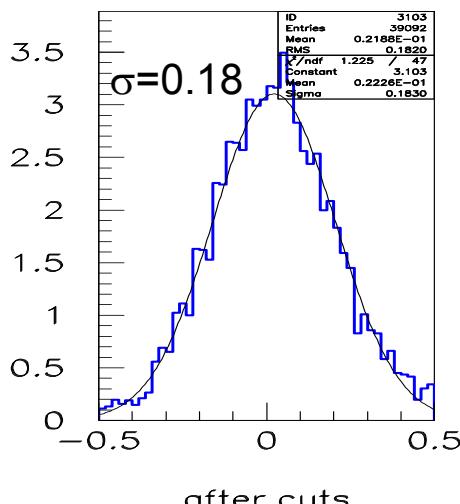
all events



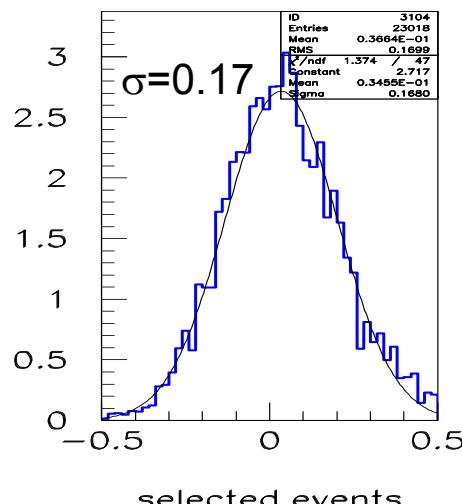
reconstructed events



events with e track



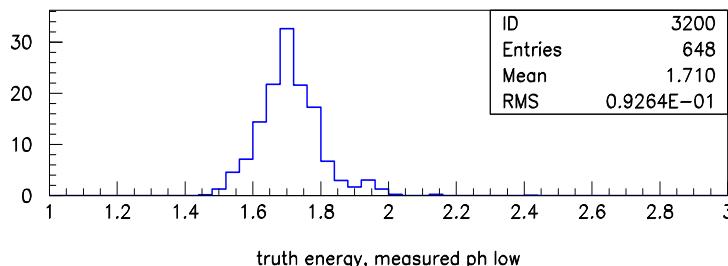
after cuts



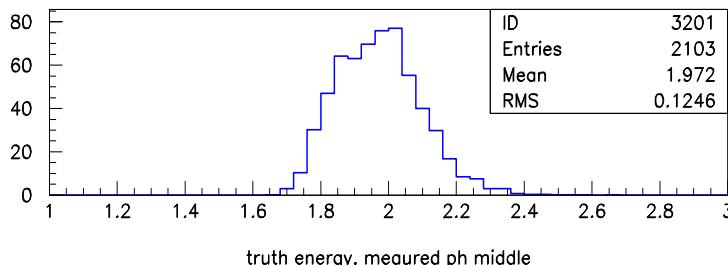
selected events

# Total energy resolution

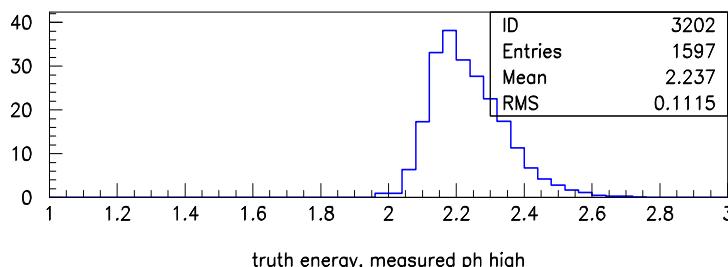
- ❖ Dividing the selected signal sample into three approximately equal pulse height bins the truth energy distributions for the three bins are shown below
- ❖ TA detector has some sensitivity to energy structure, the standard detector rather little



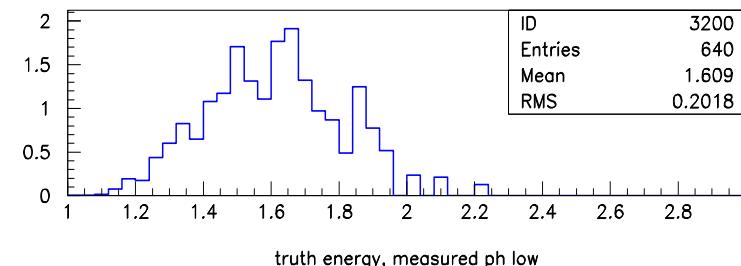
truth energy, measured ph low



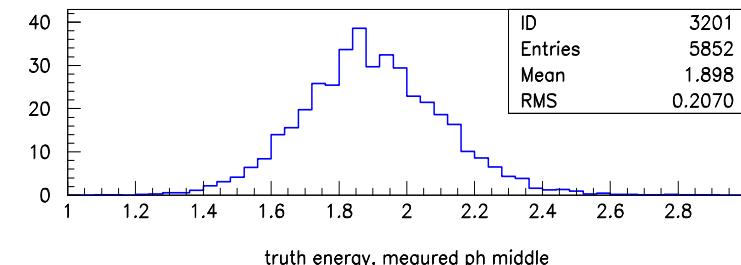
truth energy, measured ph middle



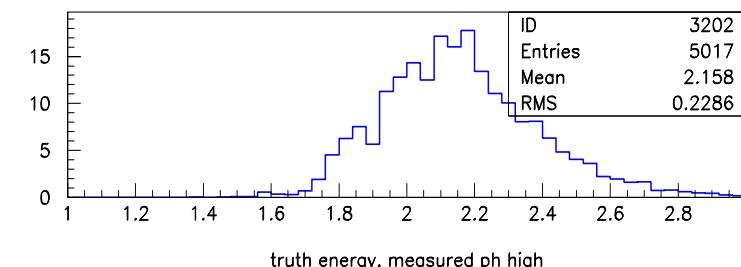
truth energy, measured ph high



truth energy, measured ph low



truth energy, measured ph middle



truth energy, measured ph high

# Other detector configurations

- ❖ Leon has generated TA detector data with half width cells
- ❖ I have had a very preliminary look with small statistics and using the same reconstruction and selection procedures
- ❖ First indications are that there is no significant improvement in the FOM but the analysis is not optimised for the narrower cells.
- ❖ What simulations of other configurations do we need to do for the next PAC document?

# TA scan analysis

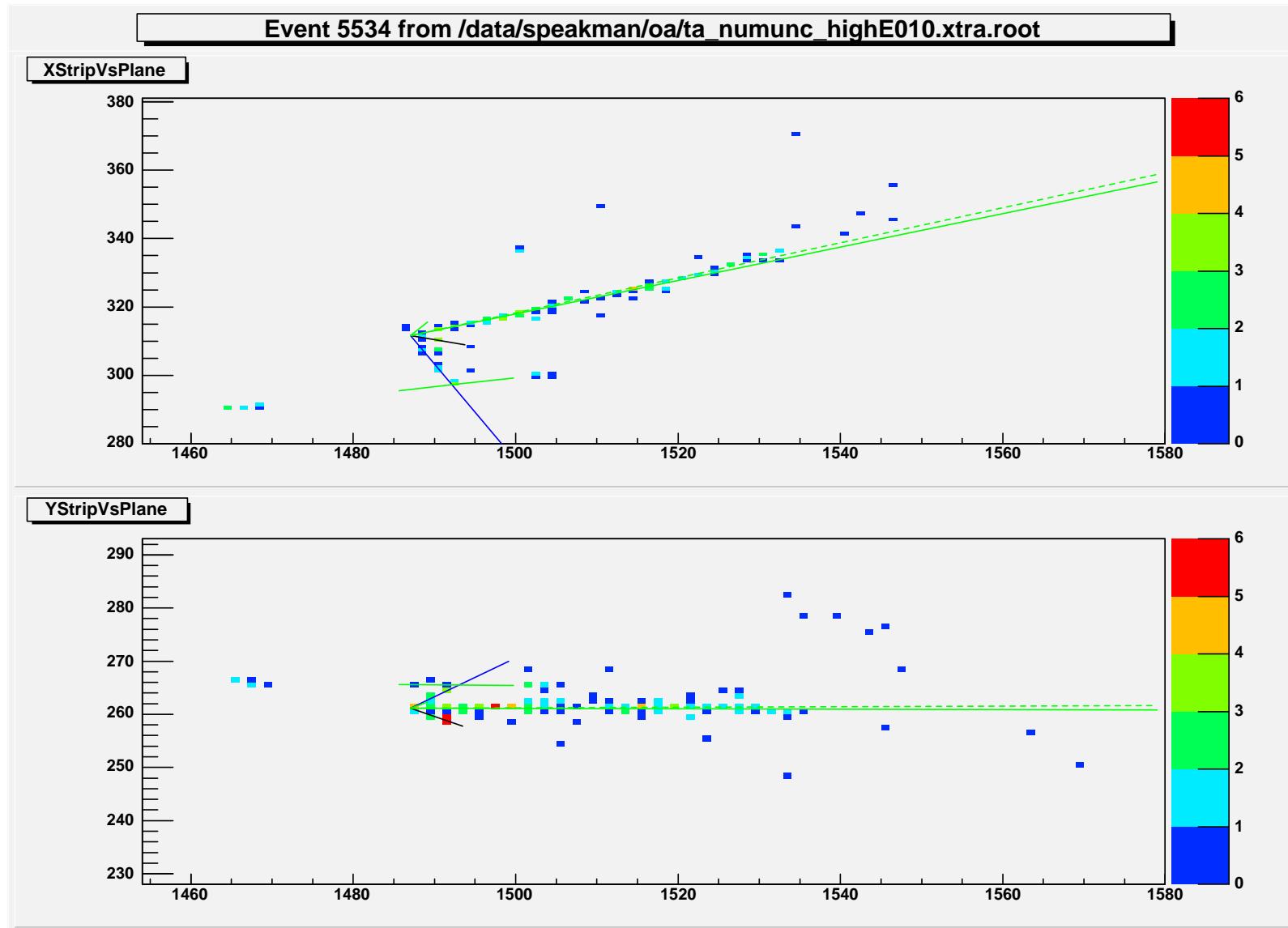
- ❖ The TA detector has in principle much better event definition and particle ID than the standard detector. To take full advantage of this would require a much better reconstruction and analysis program than I currently possess
- ❖ What is the ultimate capability of the TA detector? Use our own neural network to get some idea.
- ❖ Make coarse initial cuts which reduce the background with little effect on the signal
  - Event length
  - Event pulse height
  - An electron track candidate (>1.3 hits/plane in the track)
- ❖ Generate a typical experiment with a random admixture of  $\mu$  CC, nc and e CC events (998 events)
- ❖ Two scans, blind with no knowledge of the truth;
  - One by me, using my “physics judgement”
  - One by a summer student, Eric Chitambar using the criteria
    - A clear track in both views traceable back to a vertex
    - At least 45% of the track has multiple hits per plane
    - At least 40% of the total hits belong to the electron track

# Scan results, TA detector

$\Delta m^2 = 0.0025 \text{ eV}^2$   $\sin^2 2\theta_{23} = 1.0$   $\sin^2 2\theta_{13} = 0.10$  125 kton-years  
3.7x10<sup>20</sup> pot 810 km from Fermilab 12 km off-axis

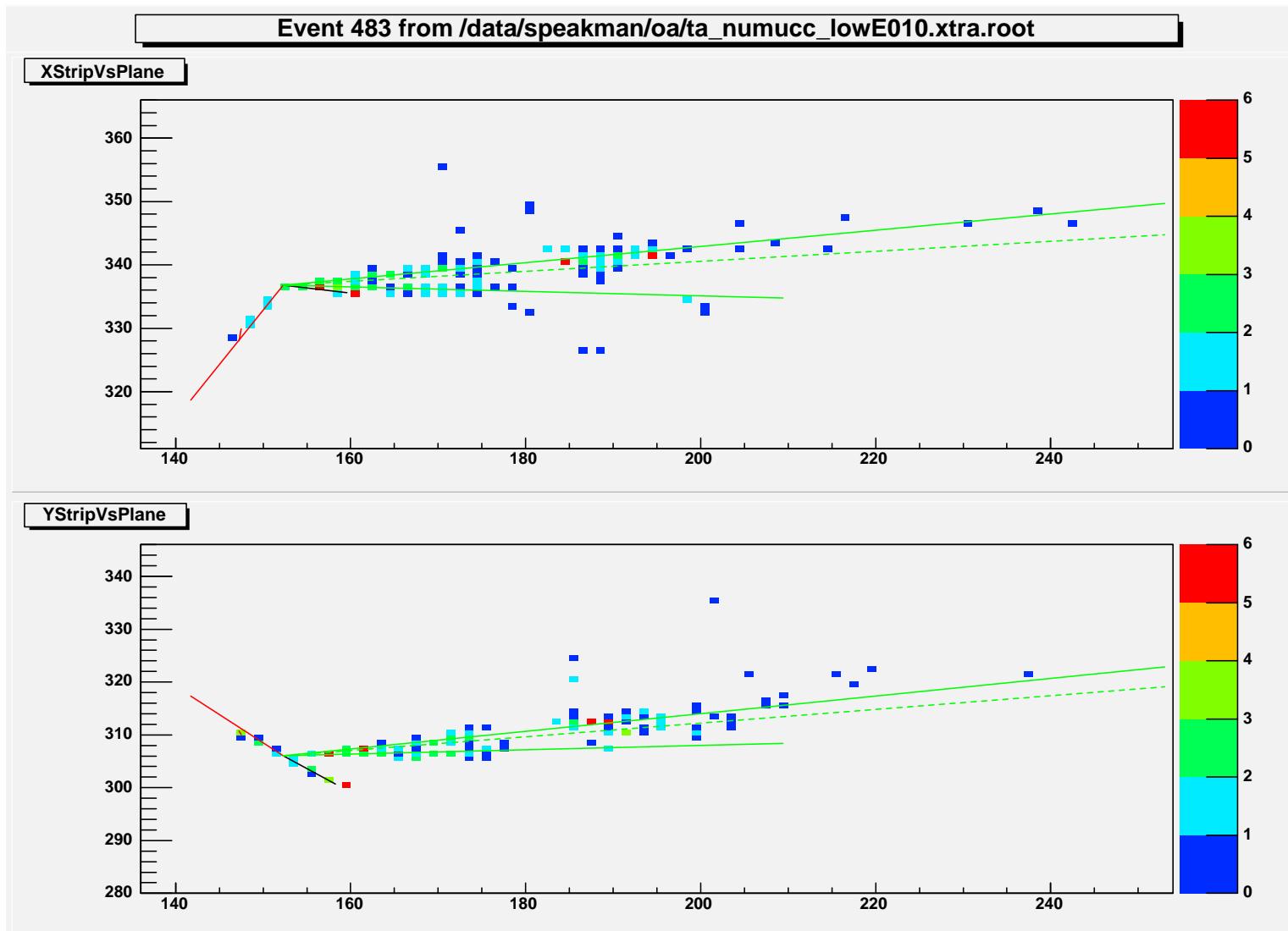
	$\mu$ CC	nc	$e_{\text{beam}}$	$e_{\text{osc}}$	FOM
Generated	1236	3725	92	312	
Recon+containment	787	2242	63	223	
Length+ph+etrack	174	598	24	201	
Generated experiment	173	605	22	198	
Pjl scan possibles	6	34	16	143	19.1
Pjl scan probables	2	11	14	113	21.7
Eric scan	5	21	17	148	22.6
My selection program	0.8	5.0	5.3	64.5	19.1
My selection program-expt	1	4	6	63	19.0
Standard detector selection	1.1	10.5	12.7	115.4	23.4

$$\nu(2.17) \rightarrow \nu(0.34) + p(1.20) + \pi^-(0.32) + \pi^0(1.24) \rightarrow \gamma(1.21) + \gamma(0.04)$$

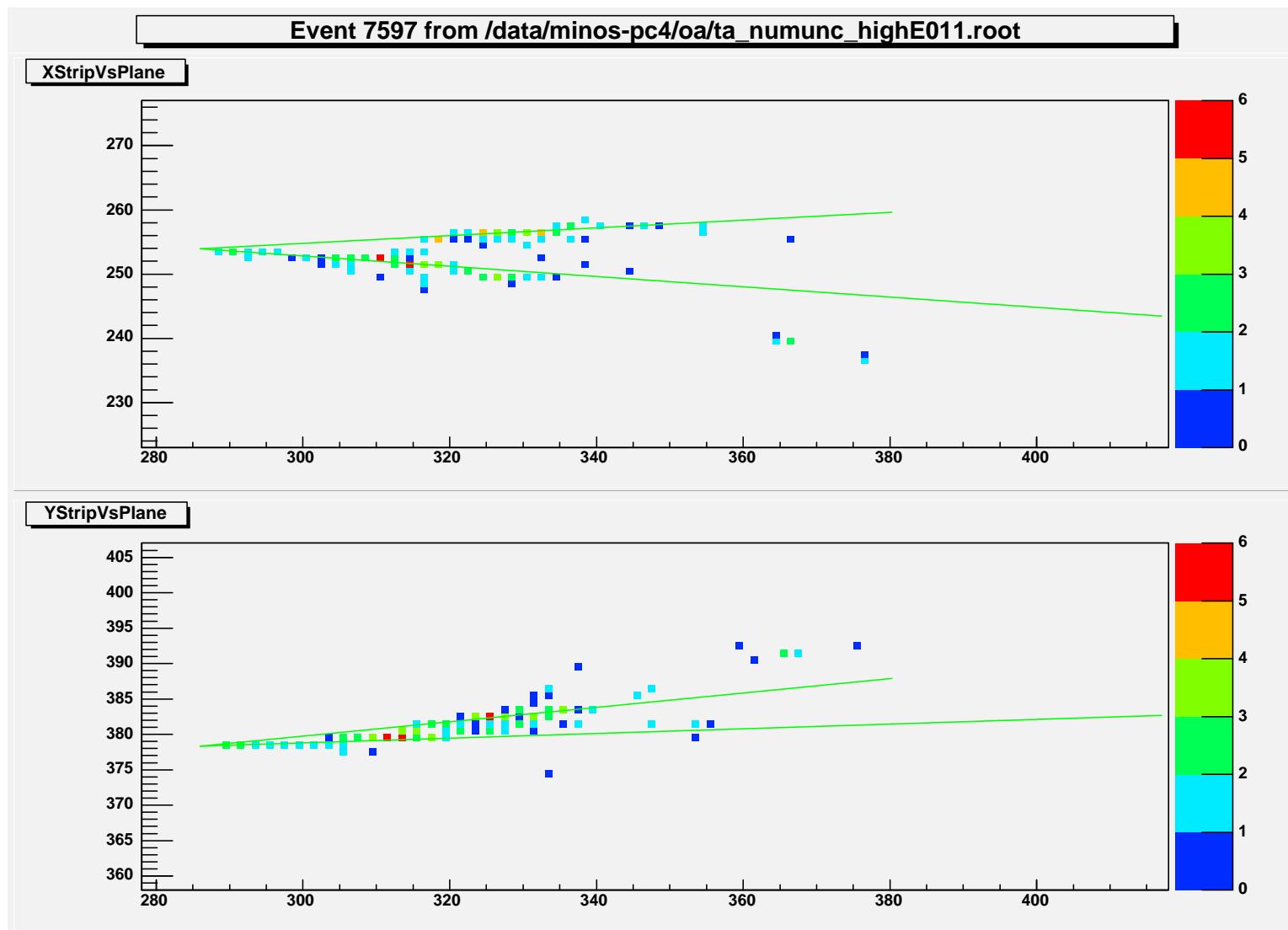


Pjl.eric

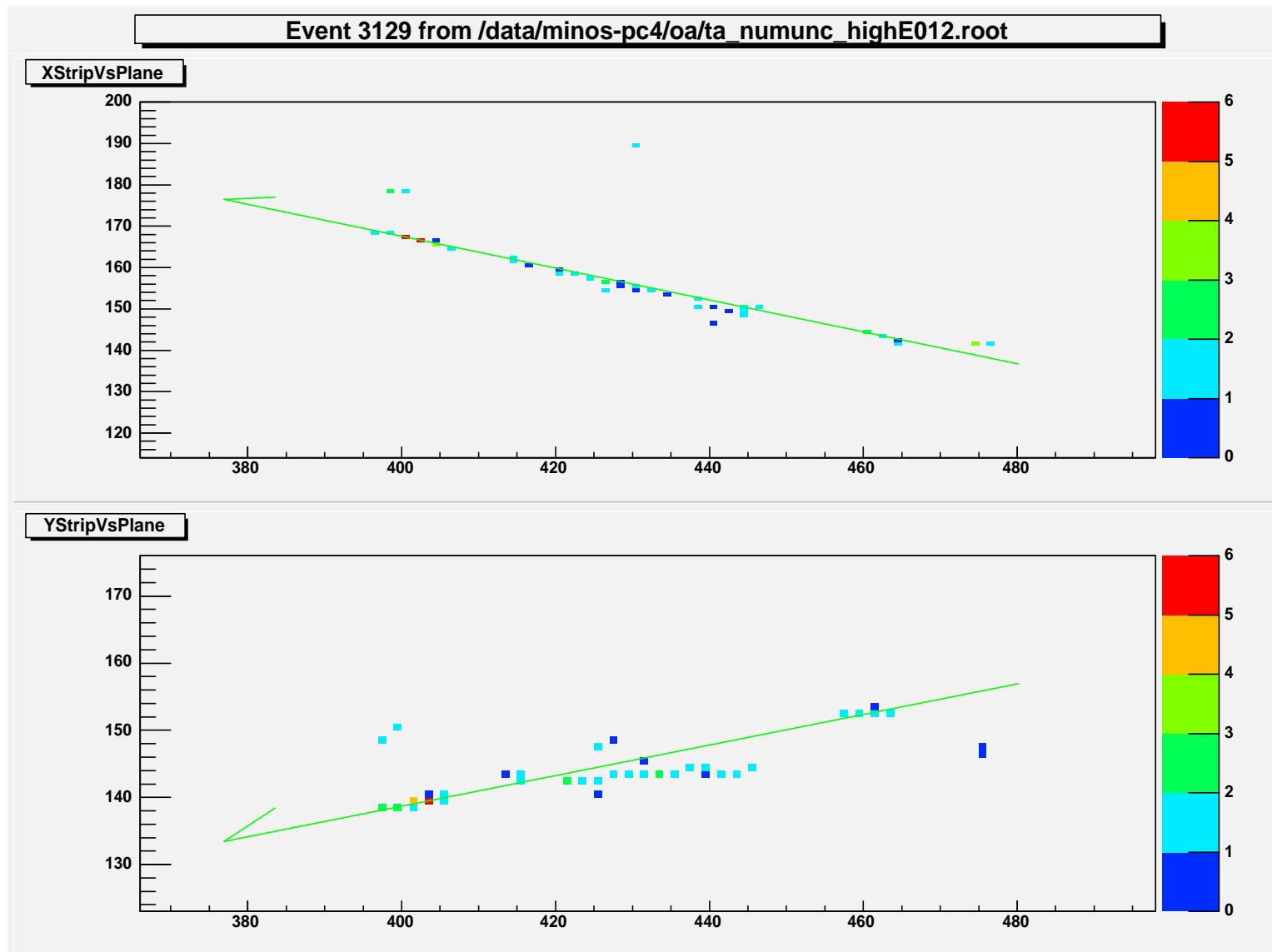
$$\nu(2.32) \rightarrow \mu^-(0.22) + p(1.22) + \pi^0(1.82) \rightarrow \gamma(1.28) + \gamma(0.54)$$



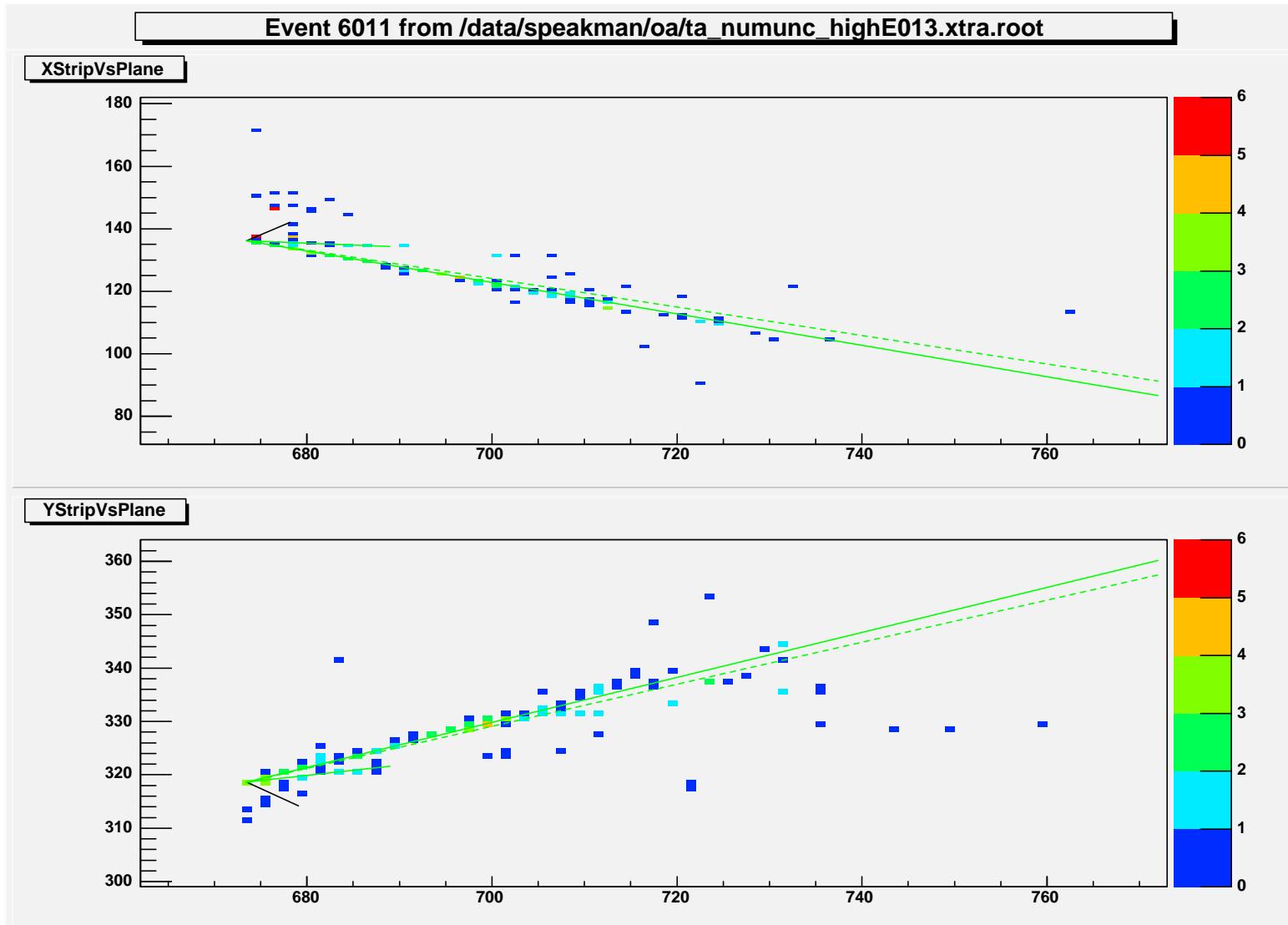
$$\nu(2.44) \rightarrow \nu(0.22) + \pi^0(2.22) \rightarrow \gamma(0.89) + \gamma(1.33)$$



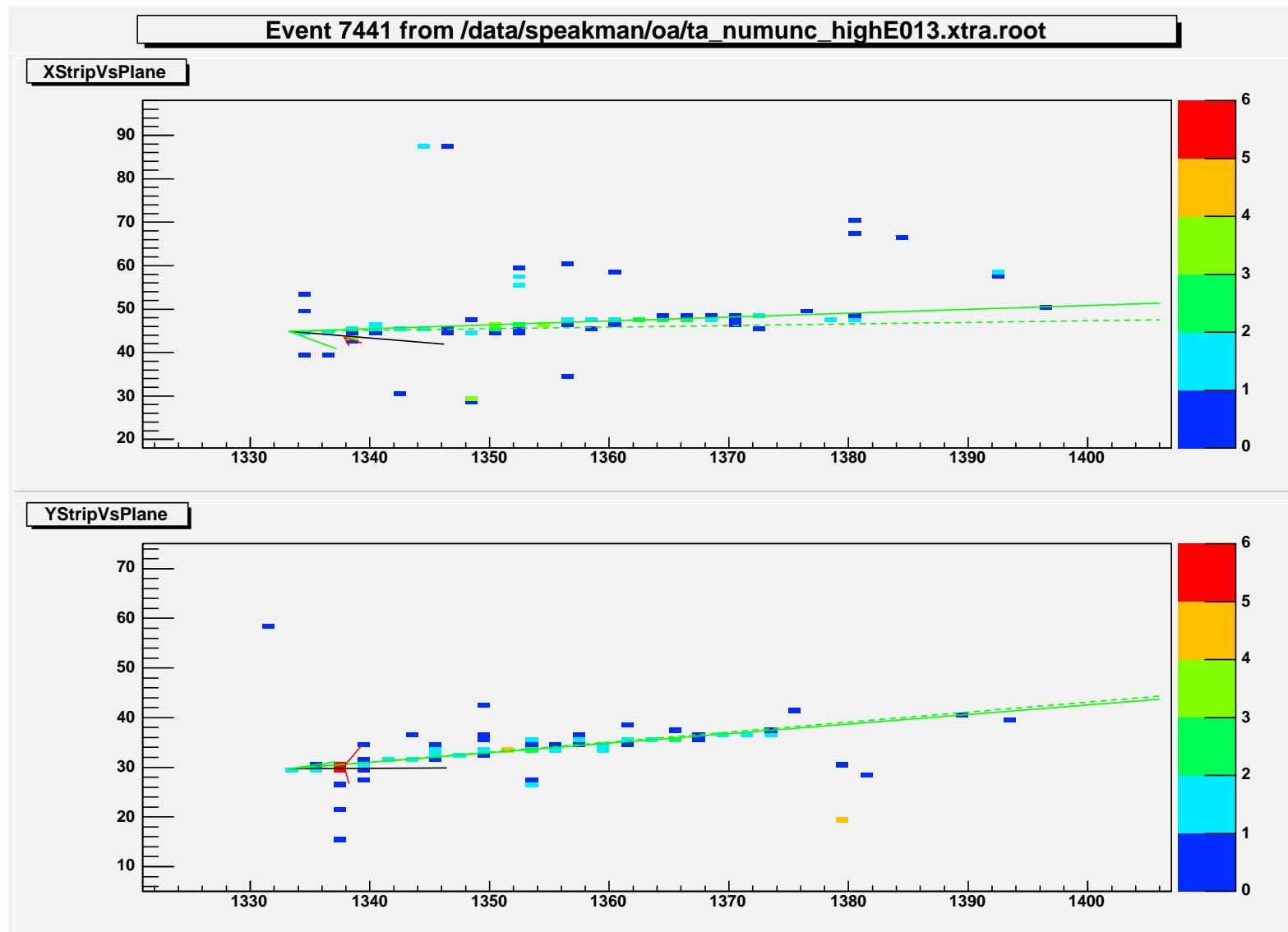
$$\nu(2.07) \rightarrow \nu(0.96) + \pi^0(1.10) \rightarrow \gamma(1.03) + \gamma(0.07)$$



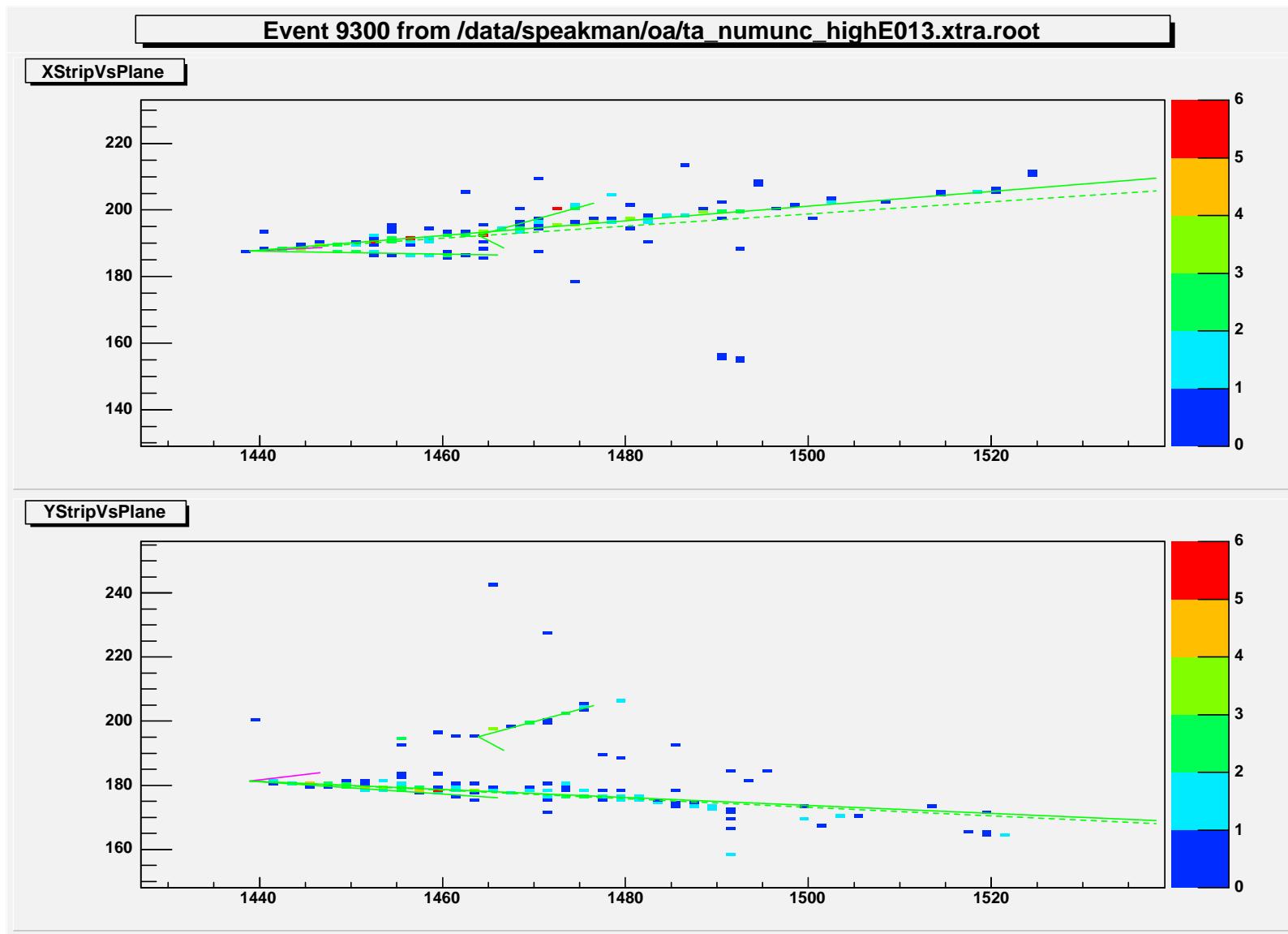
$$\nu(2.33) \rightarrow \nu(0.71) + p(1.18) + \pi^0(1.37) \rightarrow \gamma(1.22) + \gamma(0.15)$$



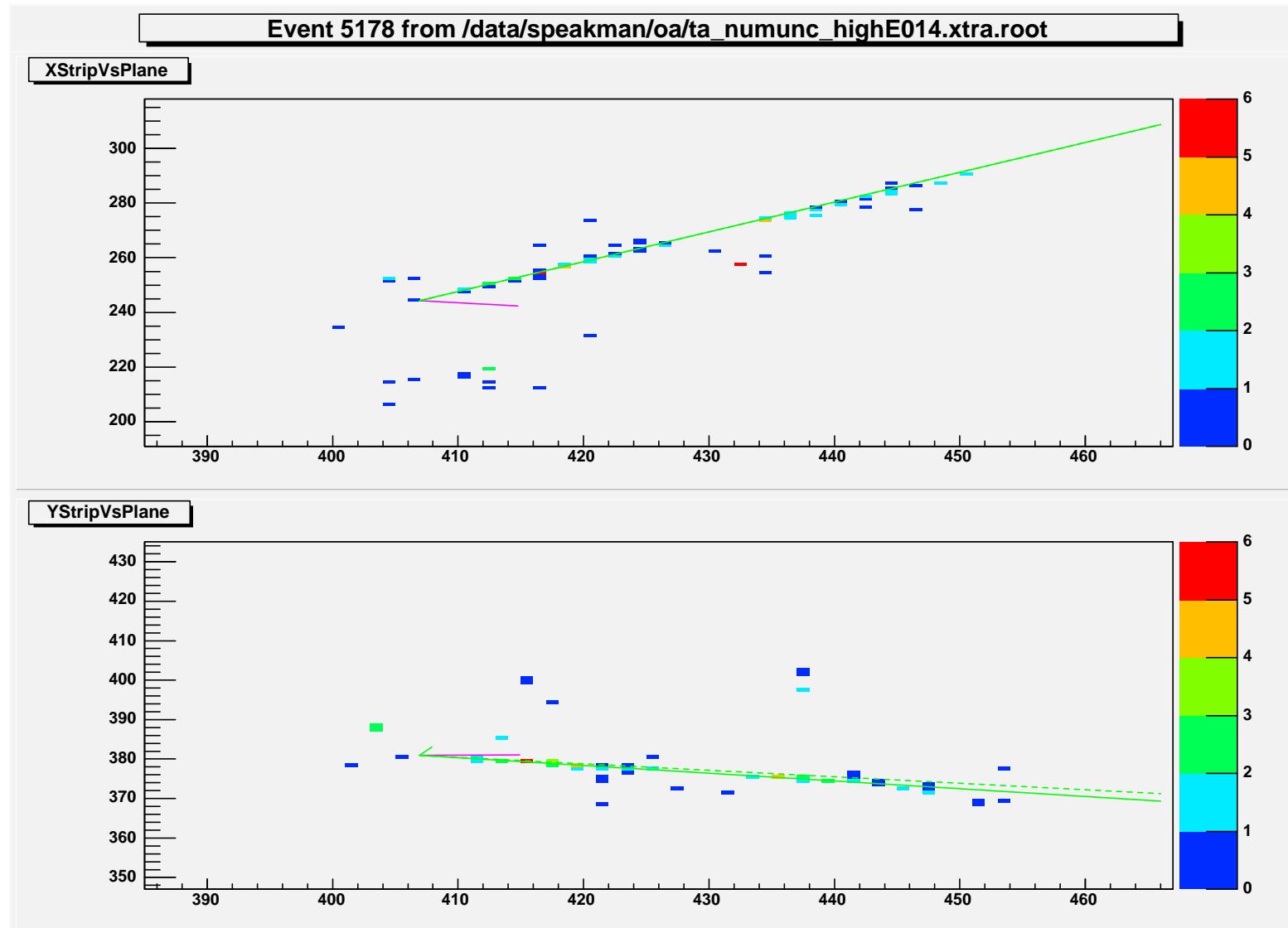
$$\nu(1.68) \rightarrow \nu(0.39) + p(1.43) + \pi^0(0.78) \rightarrow \gamma(0.73) + \gamma(0.05)$$



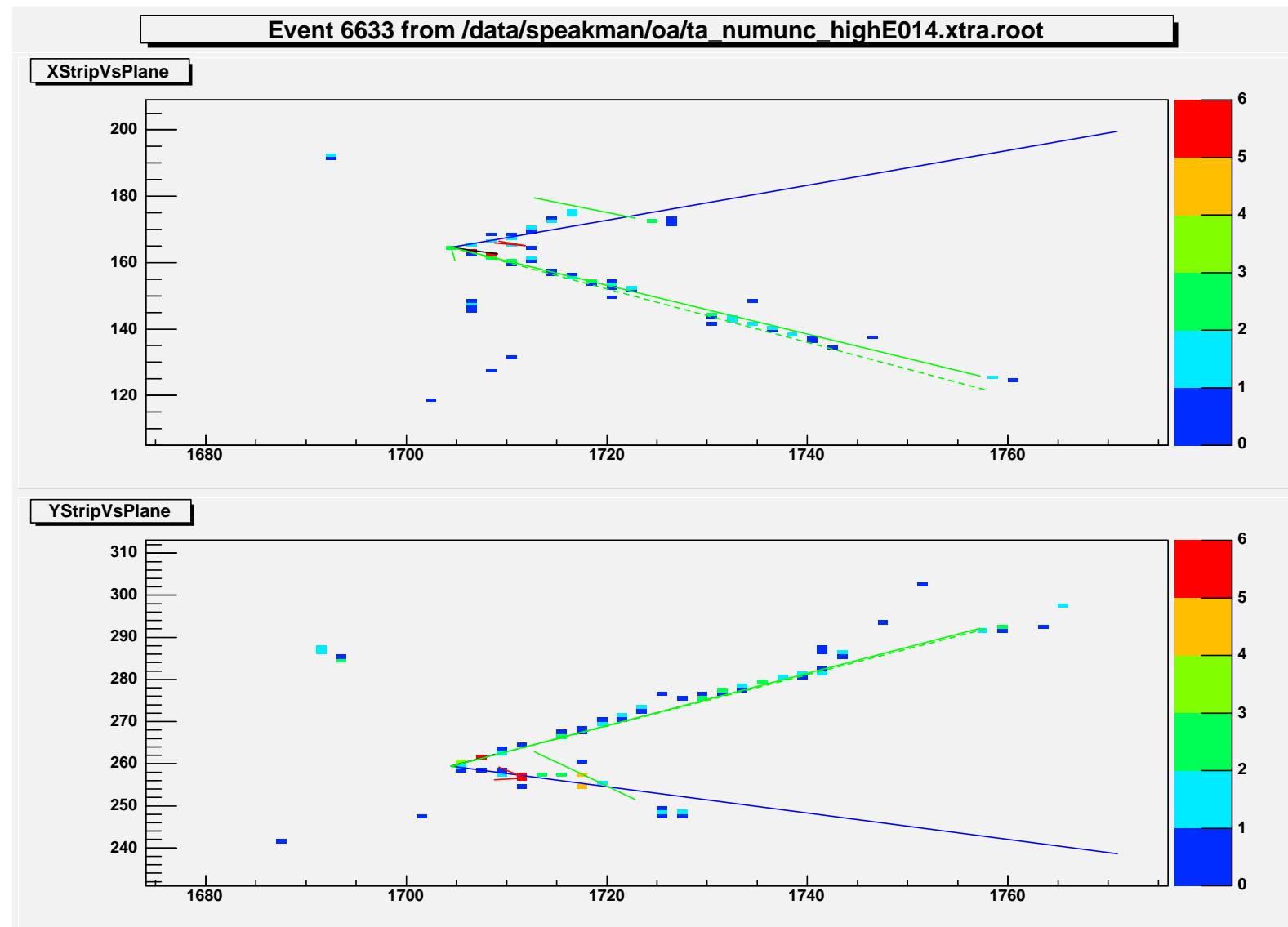
$$\nu(2.89) \rightarrow \nu(0.57) + n(1.47) + \pi^0(1.78) \rightarrow \gamma(1.53) + \gamma(0.26)$$



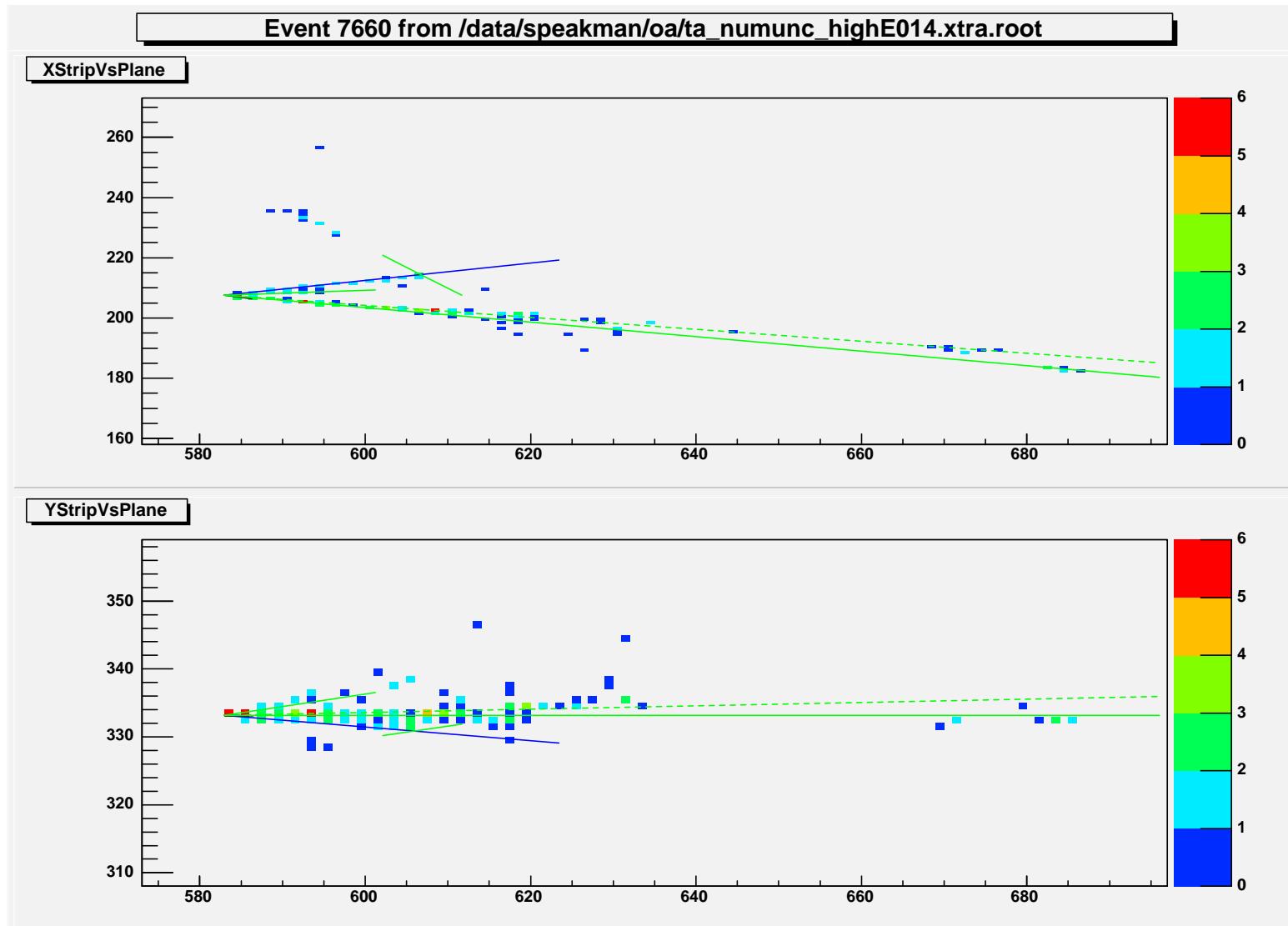
$$\nu(2.21) \rightarrow \nu(1.00) + n(1.24) + \pi^0(0.91) \rightarrow \gamma(0.89) + \gamma(0.02)$$



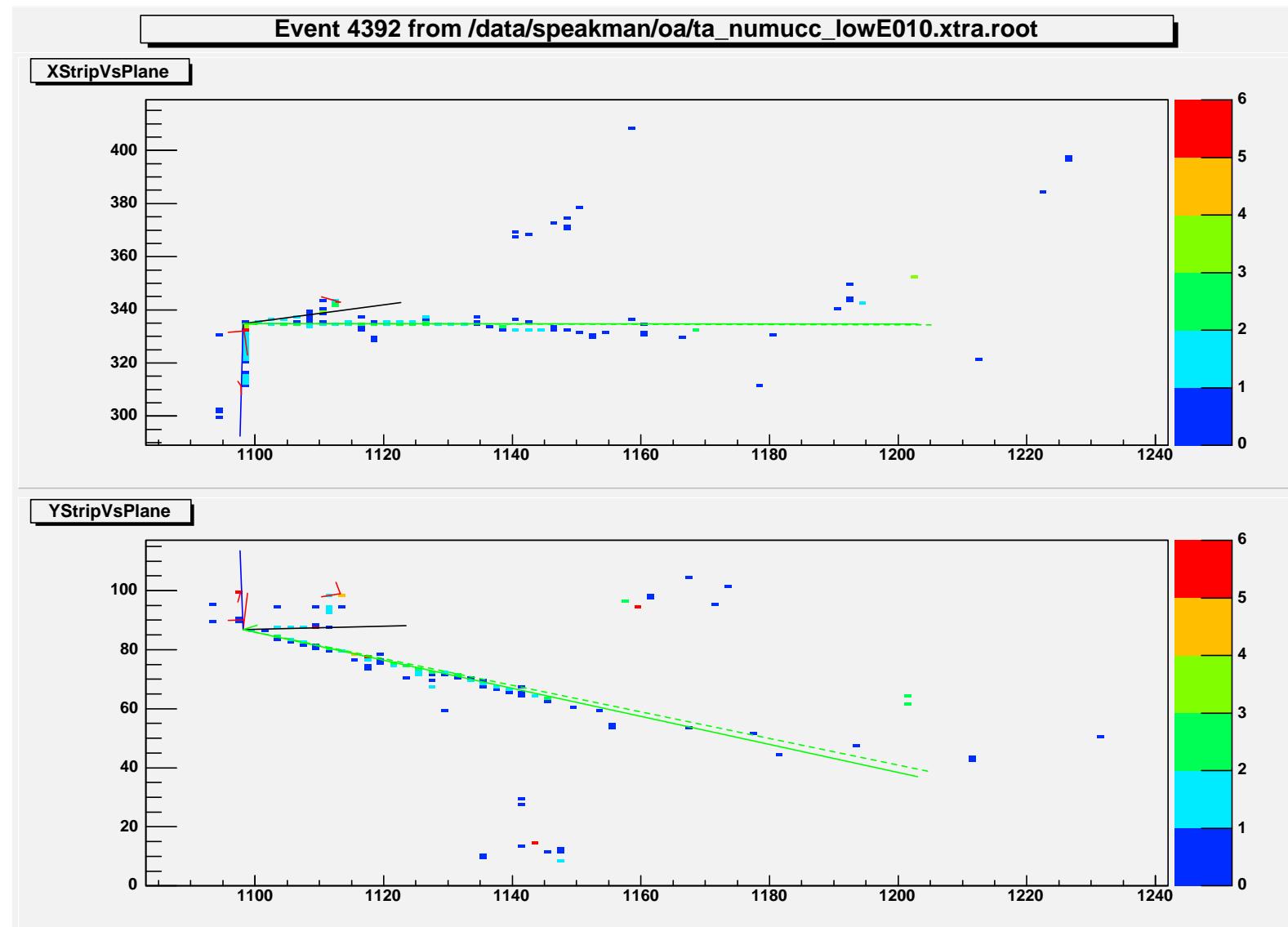
$$\nu(2.40) \rightarrow \nu(0.85) + p(1.12) + \pi^-(0.71) + \pi^0(0.66) \rightarrow \gamma(0.63) + \gamma(0.03)$$



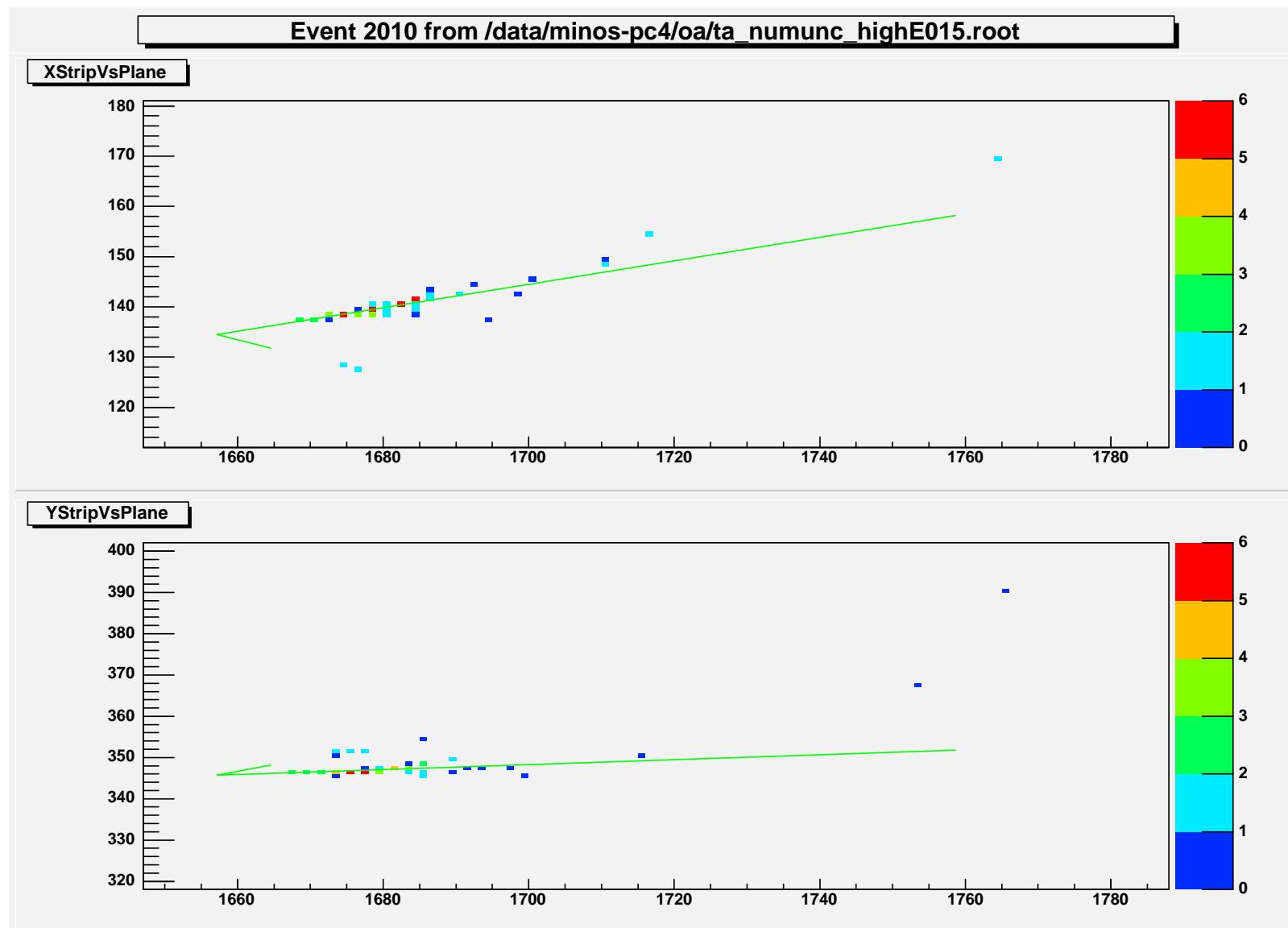
$$\nu(2.18) \rightarrow \nu(0.29) + p(1.07) + \pi^-(0.42) + \pi^0(1.34) \rightarrow \gamma(1.17) + \gamma(0.17)$$



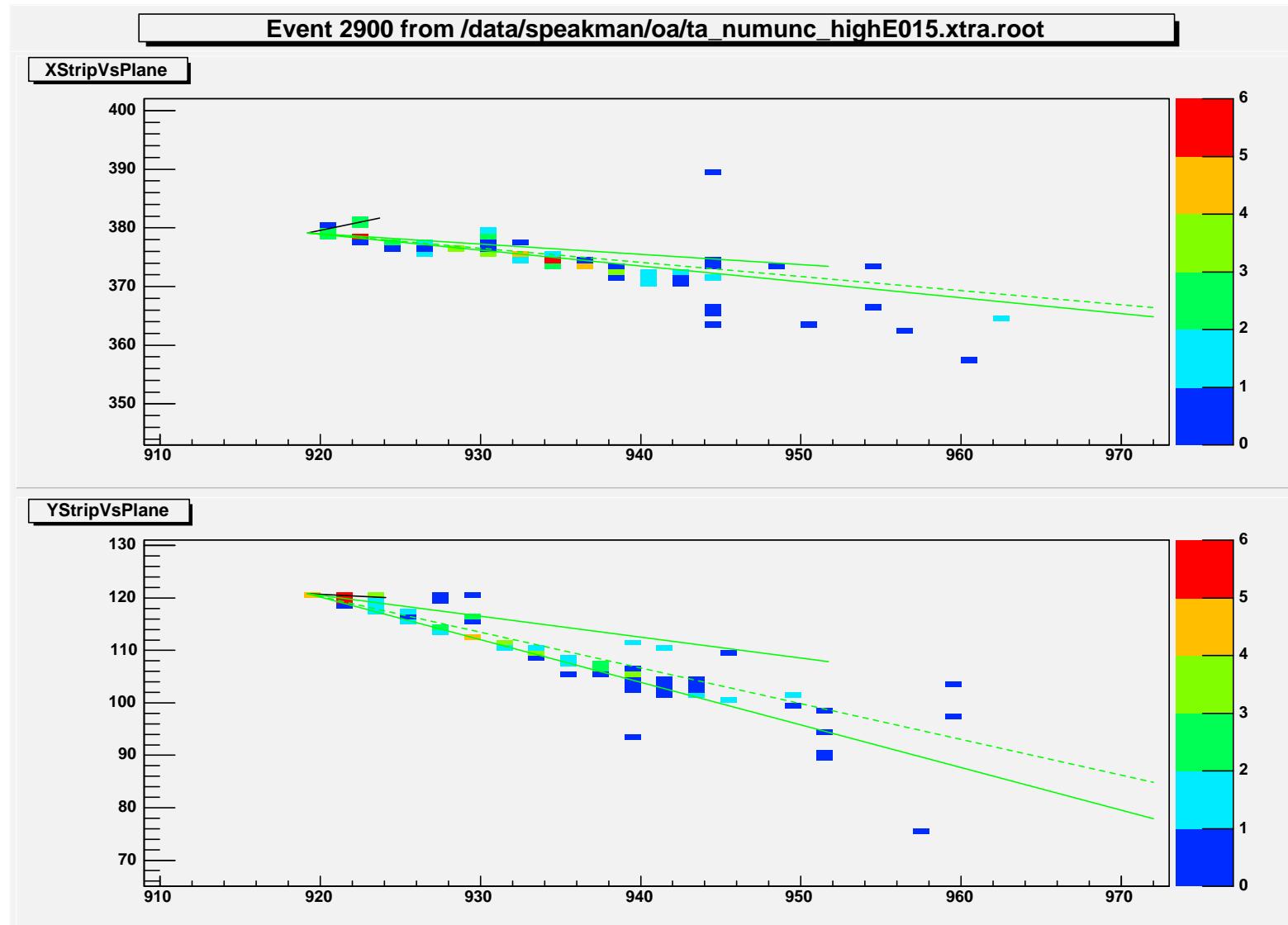
$$\nu(2.60) \rightarrow \mu^-(0.17) + p(1.87) + \pi^+(0.40) + \pi^0(1.08) \rightarrow \gamma(1.05) + \gamma(0.02)$$



$$\nu(1.93) \rightarrow \nu(0.89) + \pi^0(1.05) \rightarrow \gamma(0.97) + \gamma(0.07)$$



$$\nu(1.91) \rightarrow \nu(0.60) + p(1.12) + \pi^0(1.11) \rightarrow \gamma(0.79) + \gamma(0.32)$$



# Scan conclusions

- ❖ The scan does better, but not a lot better, in terms of FOM than the program reconstruction and selection.
- ❖ The scan gets about the same FOM with a much higher efficiency for finding signal events. The program selection gets its maximum FOM by restricting its selection to quasi-elastic type events.
- ❖ There is an irreducible background of asymmetric  $\pi^0$  decays
- ❖ The possibilities may be improved by reconstructing the gamma showers and rejecting anything which makes a  $\pi^0$
- ❖ The 25kton TA detector FOM is still not quite as good as the 50kton standard detector FOM even after the scanning but further reconstruction might make them equivalent.